CHAPTER 7

FLEXIBLE PAVEMENT THICKNESS DESIGN

7-1. General. This section presents procedures for the thickness design of flexible pavements for runways, taxiways, and other airfield areas.

a. Flexible pavements. Flexible pavements include the following:

(1) Conventional flexible pavements consisting of a bituminous concrete surface on a high quality granular base and subbase course.

(2) Stabilized pavement consisting of bituminous concrete surface course over a section which may include a stabilized base, a stabilized subbase, or any combination of the aforementioned.

(3) All bituminous pavement consisting of asphalt concrete mixtures for all courses from top of surface to subgrade.

b. Basis for thickness design. The thickness design procedures included herein for conventional flexible pavement construction are based on CBR design methods developed for airfields. The design methods for pavements that include stabilized layers are based on modifications of the conventional procedures utilizing thickness equivalencies developed from highway and airfield test experience.

7-2. Flexible pavement design curves. Table 7-1 tabulates the flexible pavement design curves for use in this manual. The curves are identified by class or category, gear configuration, and a typical design aircraft where appropriate. The individual curves indicate the total required thickness of pavement for gross aircraft weight and aircraft passes. The Army defines a pass as one movement of the design aircraft past a given point on the pavement.

7-3. Design requirements. Flexible pavement designs must provide:

- Sufficient compaction of the subgrade and each pavement layer to prevent objectionable settlement under concentrated and repeated traffic. Compaction requirements are given in table 3-3.

- Adequate thickness of quality pavement components above the subgrade to prevent detrimental subgrade deformation, excessive deflection of the pavement surface, and excessive tensile strain in the bituminous pavement material under traffic.

- A stable, weather resistant, wear resistant, nonskid surface.

7-4. Thickness design. From the procedures included herein, the total thickness of the pavement, as well as the individual courses, may be

Table 7-1. Flexible Pavement Design Curves

Identification	Service and Designation	Gear Configuration	Typical Aircraft
Figure 7-1	Army Class I	single wheel tricycle	OV-1
Figure 7-2	Army Class II	dual wheel tricycle	CH-54
Figure 7-3	Army Class III	single tandem tricycle	C-130
Figure 7-4	Air Force-Light Load*	single wheel tricycle	-----
Figure 7-5 (a) and (b)	Air Force-Medium Load*	dual tandem tricycle	-----
Figure 7-6 (a) and (b)	Air Force-Heavy Load*	twin twin bicycle	-----
Figure 7-7	Air Force-Shoulder Pavement*	outrigger gear and vehicles	-----
Figure 7-8	Air Force-Shortfield Pavement*	single tandem tricycle	-----

*Air Force pavement design curves are provided for reference only.

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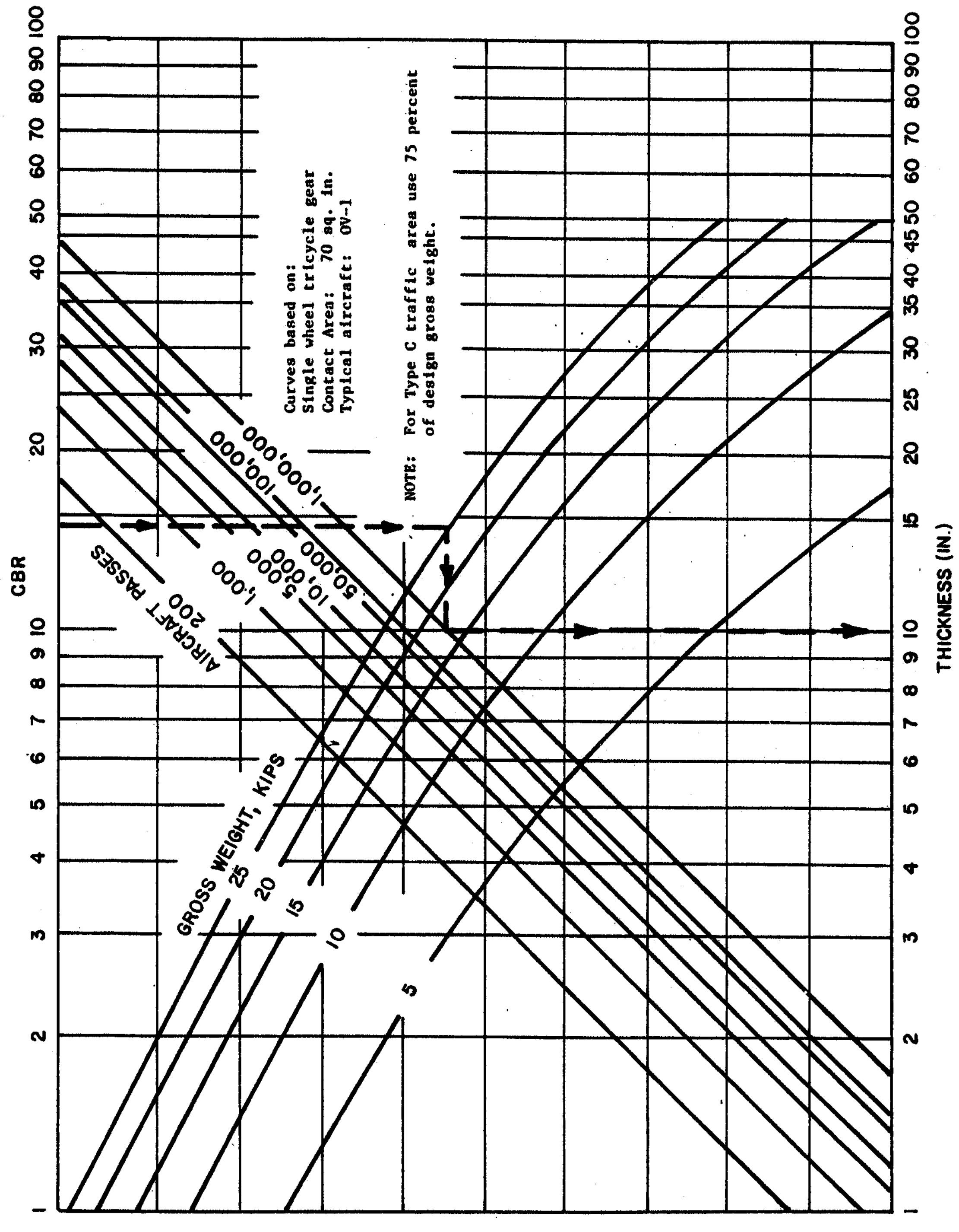

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FIGURE 7-1. FLEXIBLE PAVEMENT DESIGN CURVES, ARMY CLASS I AIRFIELD, TYPE B AND C TRAFFIC AREAS

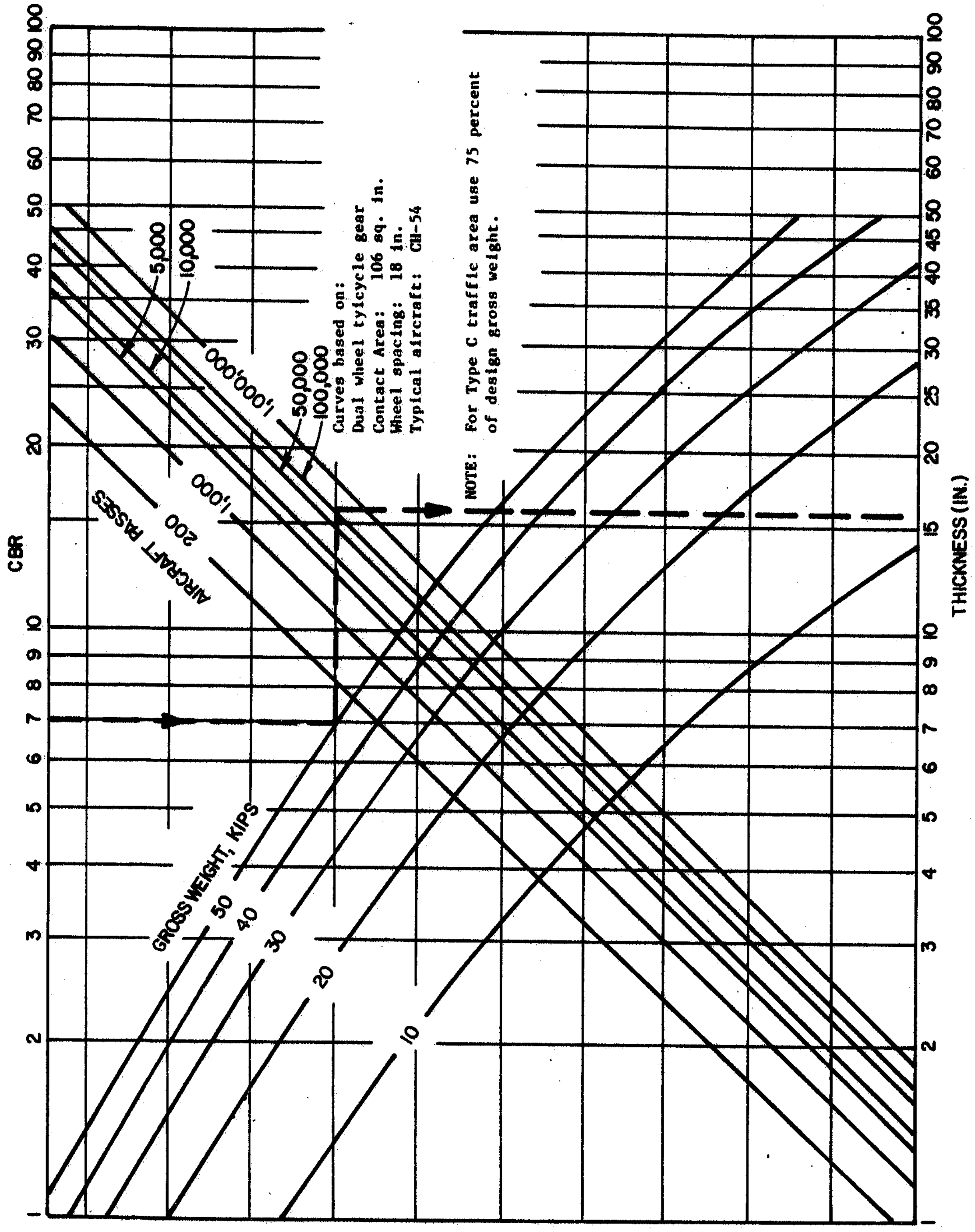

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FIGURE 7-2. FLEXIBLE PAVEMENT DESIGN CURVES,
ARMY CLASS II AIRFIELD, TYPE B AND C TRAFFIC AREAS

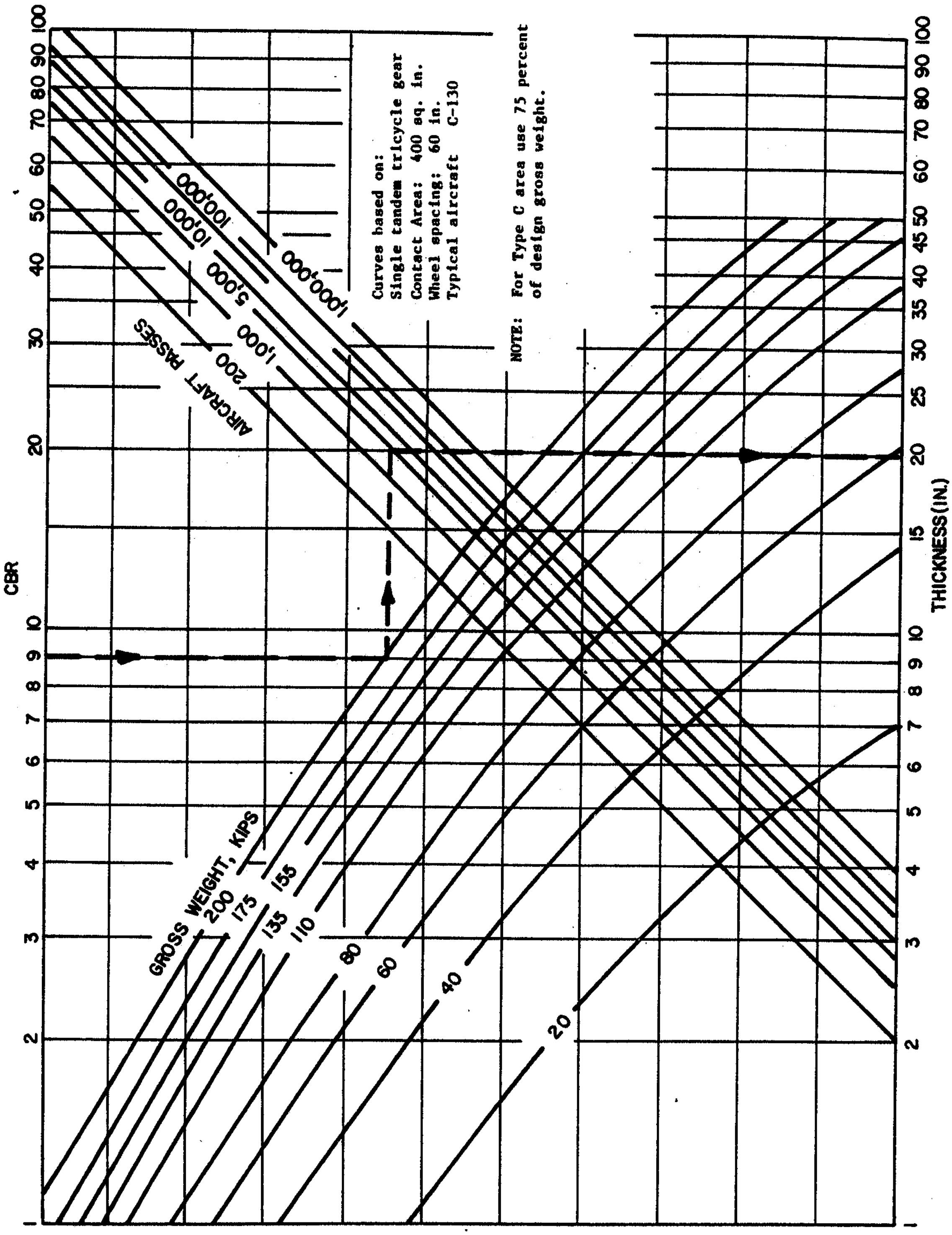

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FIGURE 7-3. FLEXIBLE PAVEMENT DESIGN CURVES,
ARMY CLASS III AIRFIELD, TYPE B AND C TRAFFIC AREAS

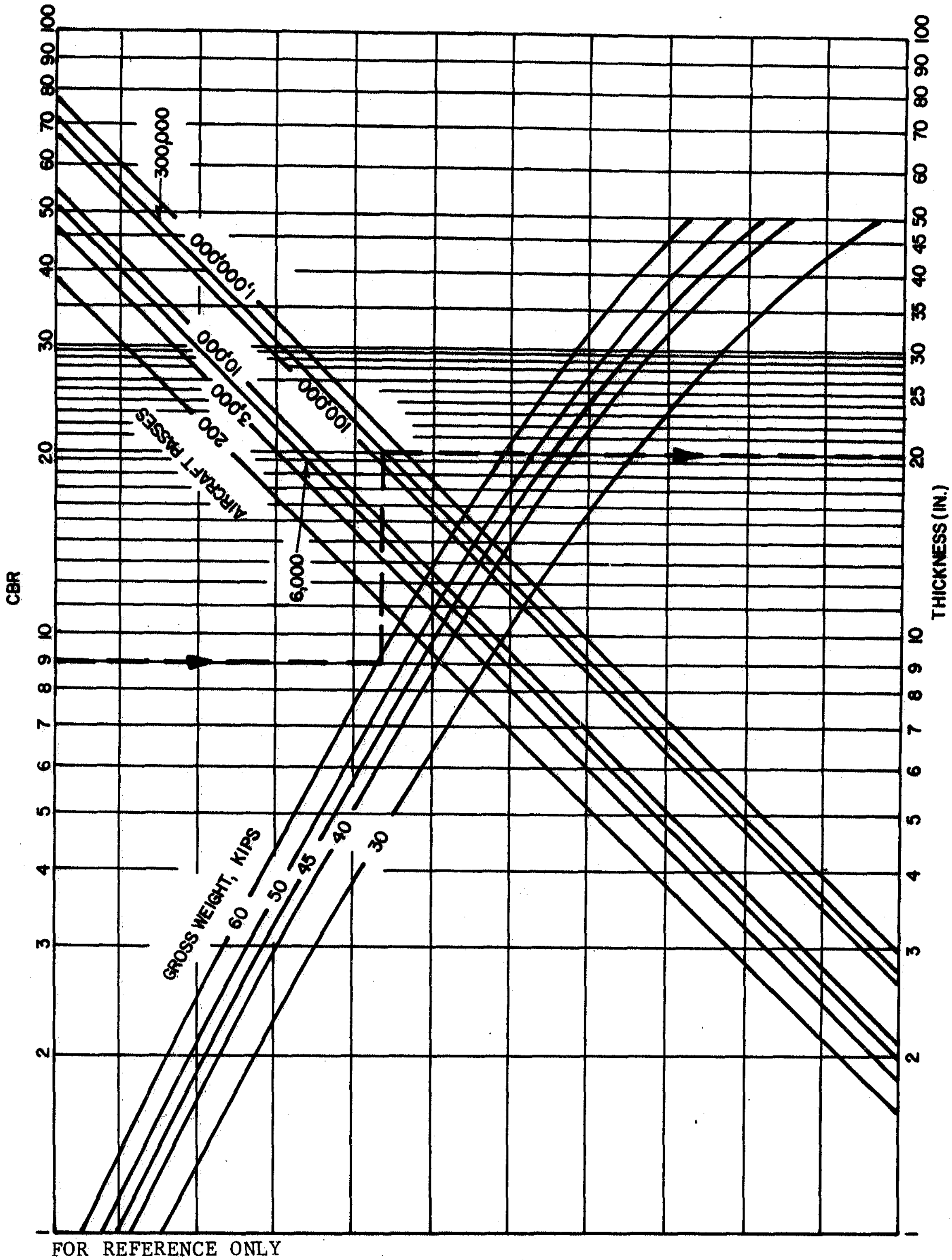

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FIGURE 7-4. FLEXIBLE PAVEMENT DESIGN CURVES,
AIR FORCE LIGHT-LOAD PAVEMENT, TYPE B AND C
TRAFFIC AREAS AND OVERRUNS

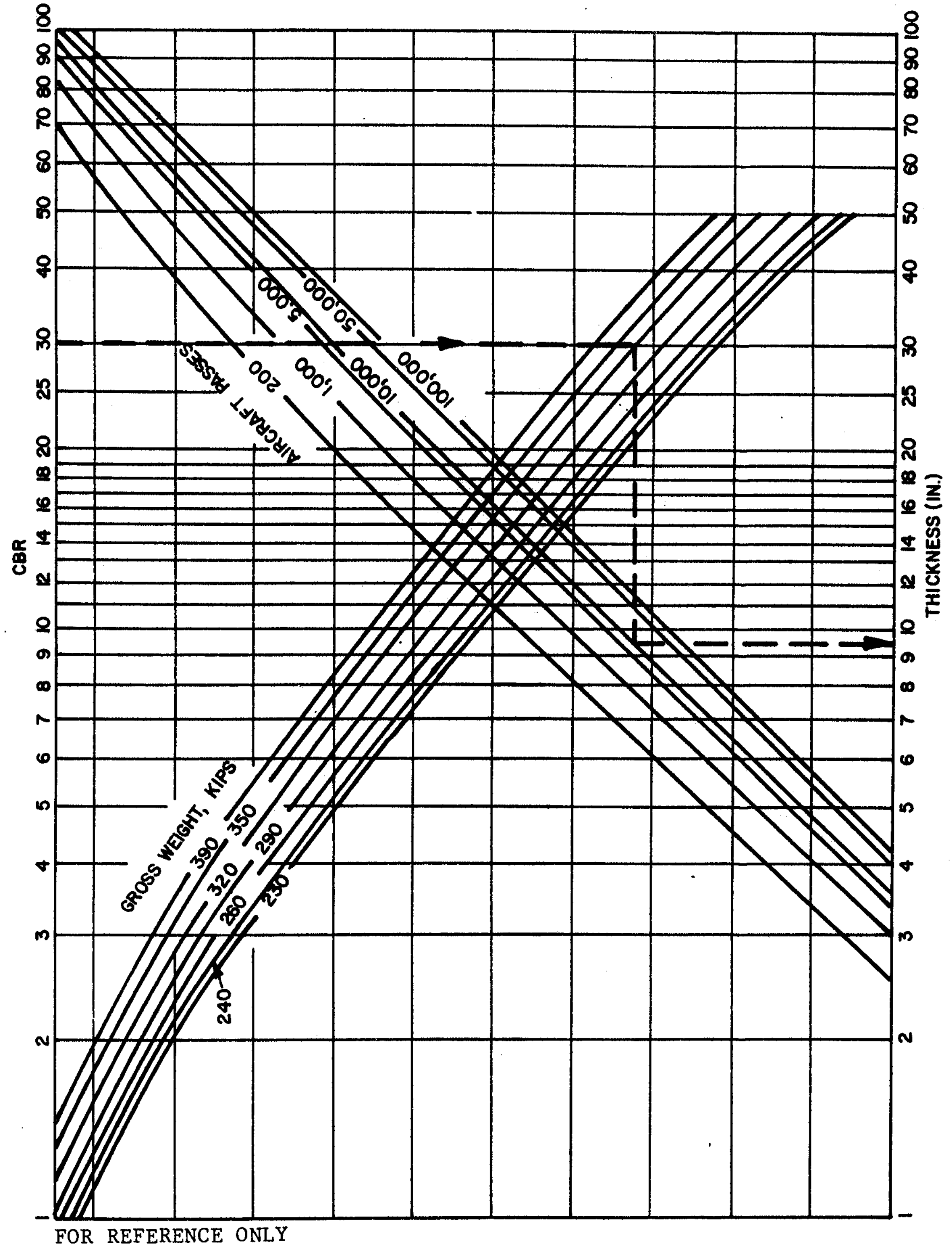

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FIGURE 7-5a. FLEXIBLE PAVEMENT DESIGN CURVES,
AIR FORCE MEDIUM-LOAD PAVEMENT, TYPE A TRAFFIC AREAS

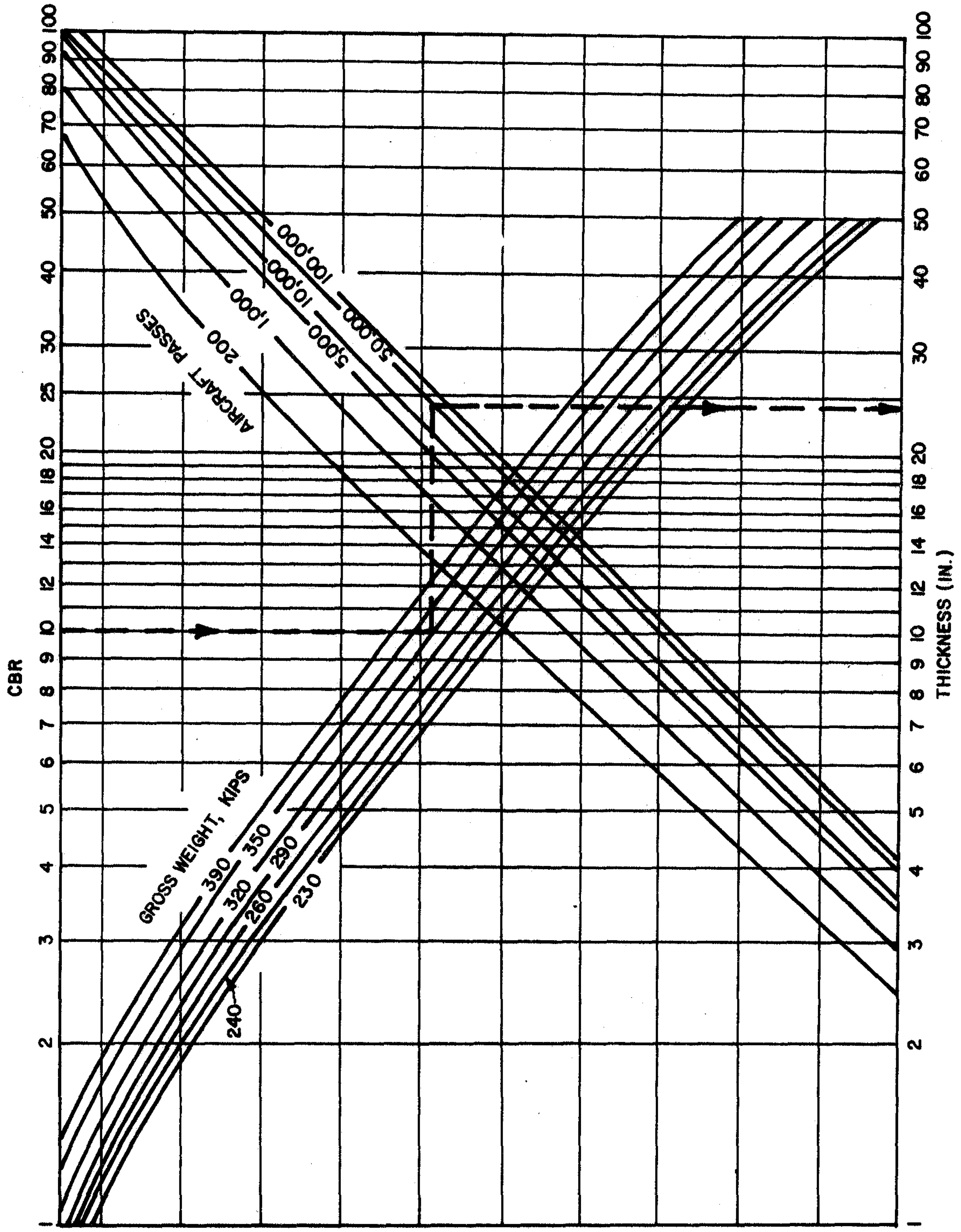

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FIGURE 7-5b. FLEXIBLE PAVEMENT DESIGN CURVES, AIR FORCE MEDIUM-LOAD PAVEMENT, TYPE B, C, AND D TRAFFIC AREAS AND OVERRUNS

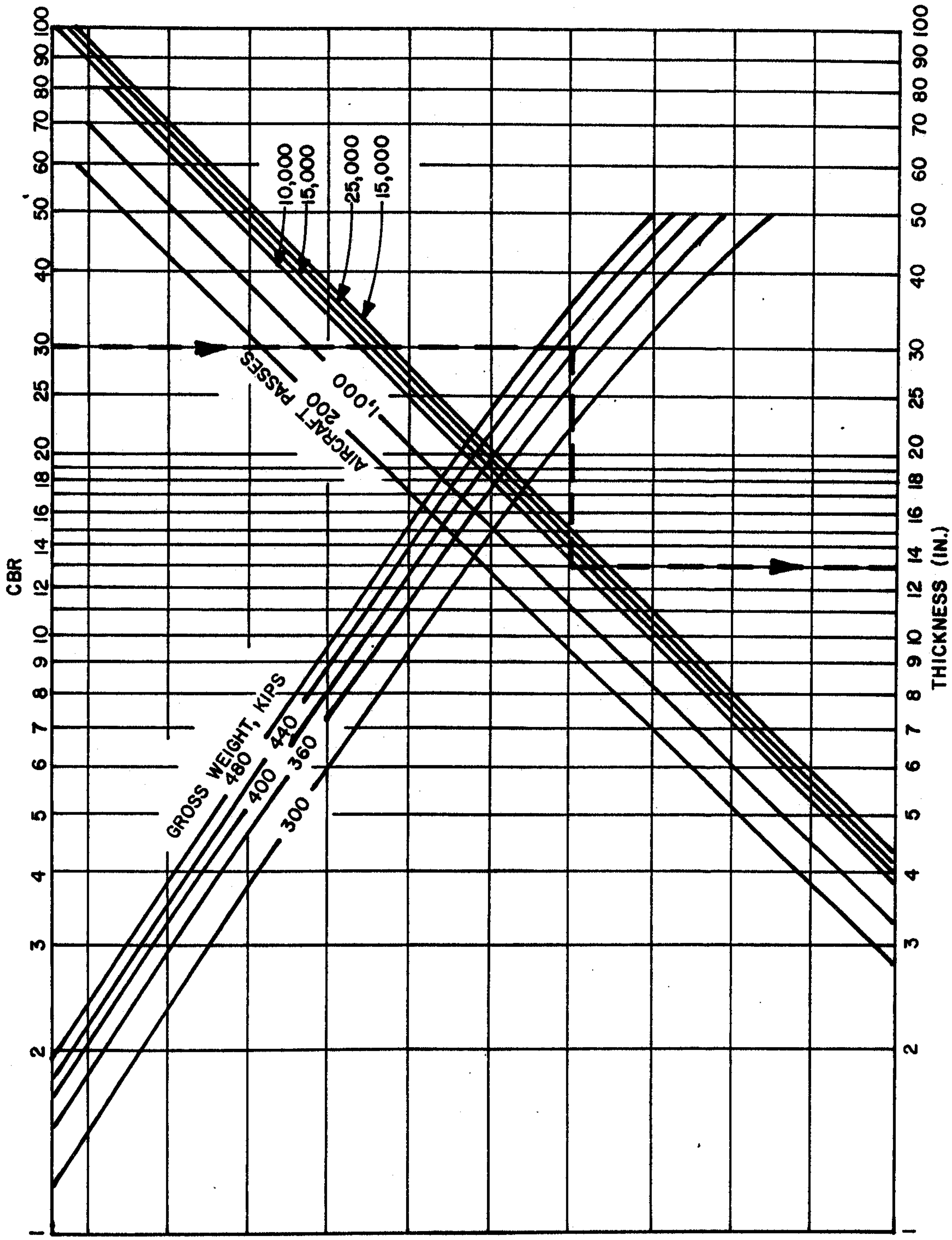

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FIGURE 7-6a. FLEXIBLE PAVEMENT DESIGN CURVES,
AIR FORCE HEAVY-LOAD PAVEMENT, TYPE A TRAFFIC AREA

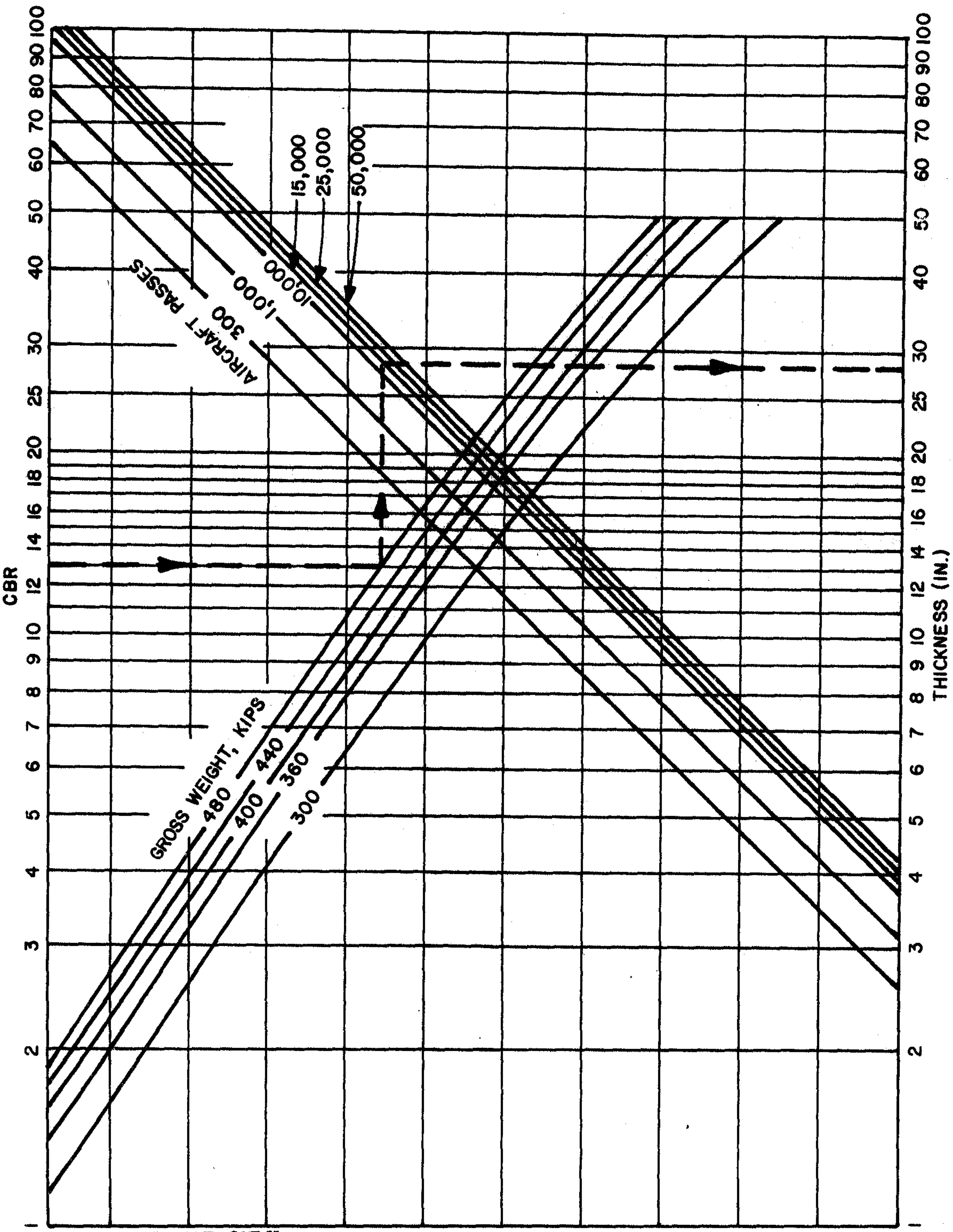

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FIGURE 7-6b. FLEXIBLE PAVEMENT DESIGN CURVES,
AIR FORCE HEAVY-LOAD PAVEMENT,
TYPES B, C, AND D TRAFFIC AREAS AND OVERRUNS.

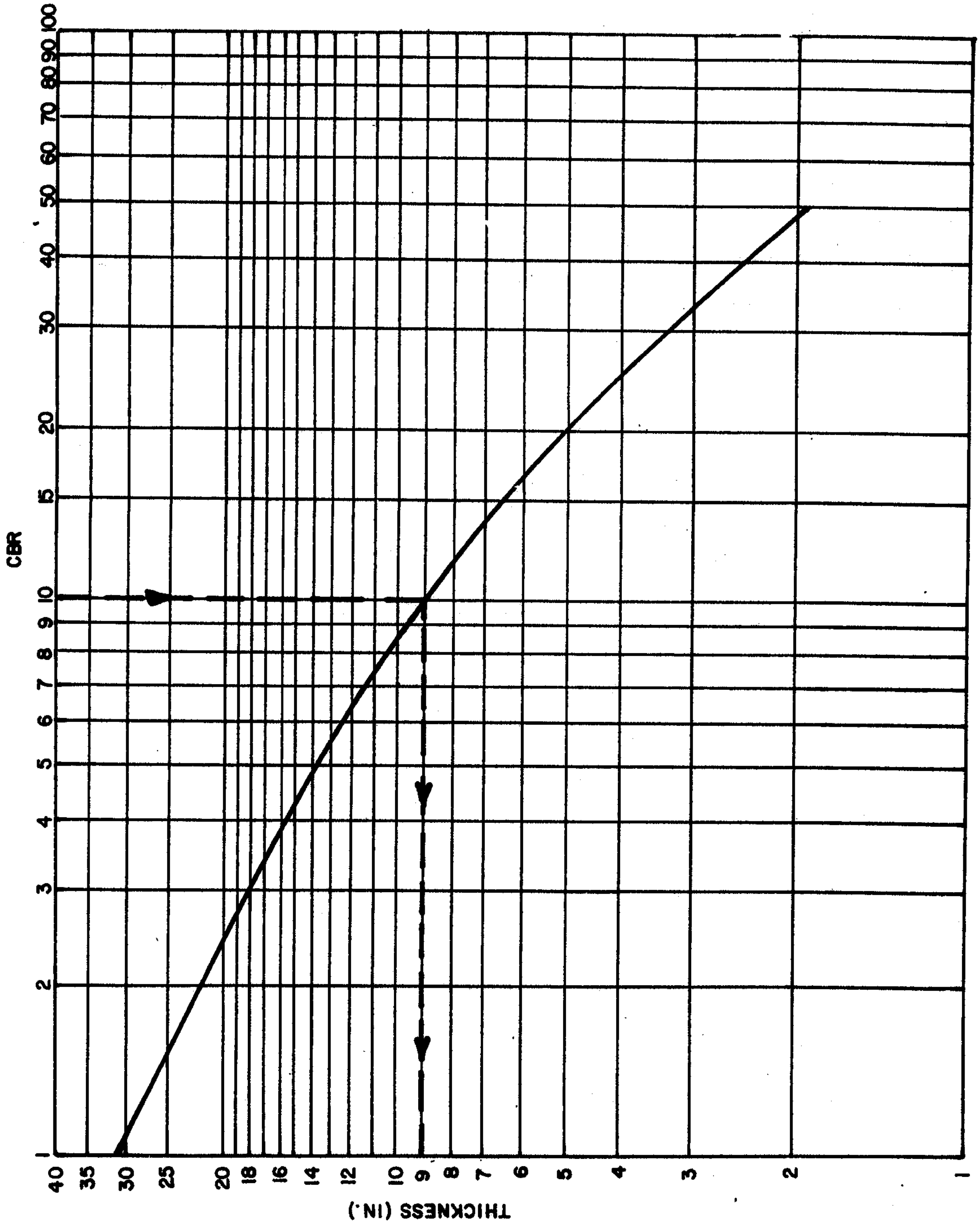

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FIGURE 7-7. FLEXIBLE PAVEMENT DESIGN CURVES
AIR FORCE SHOULDER PAVEMENT

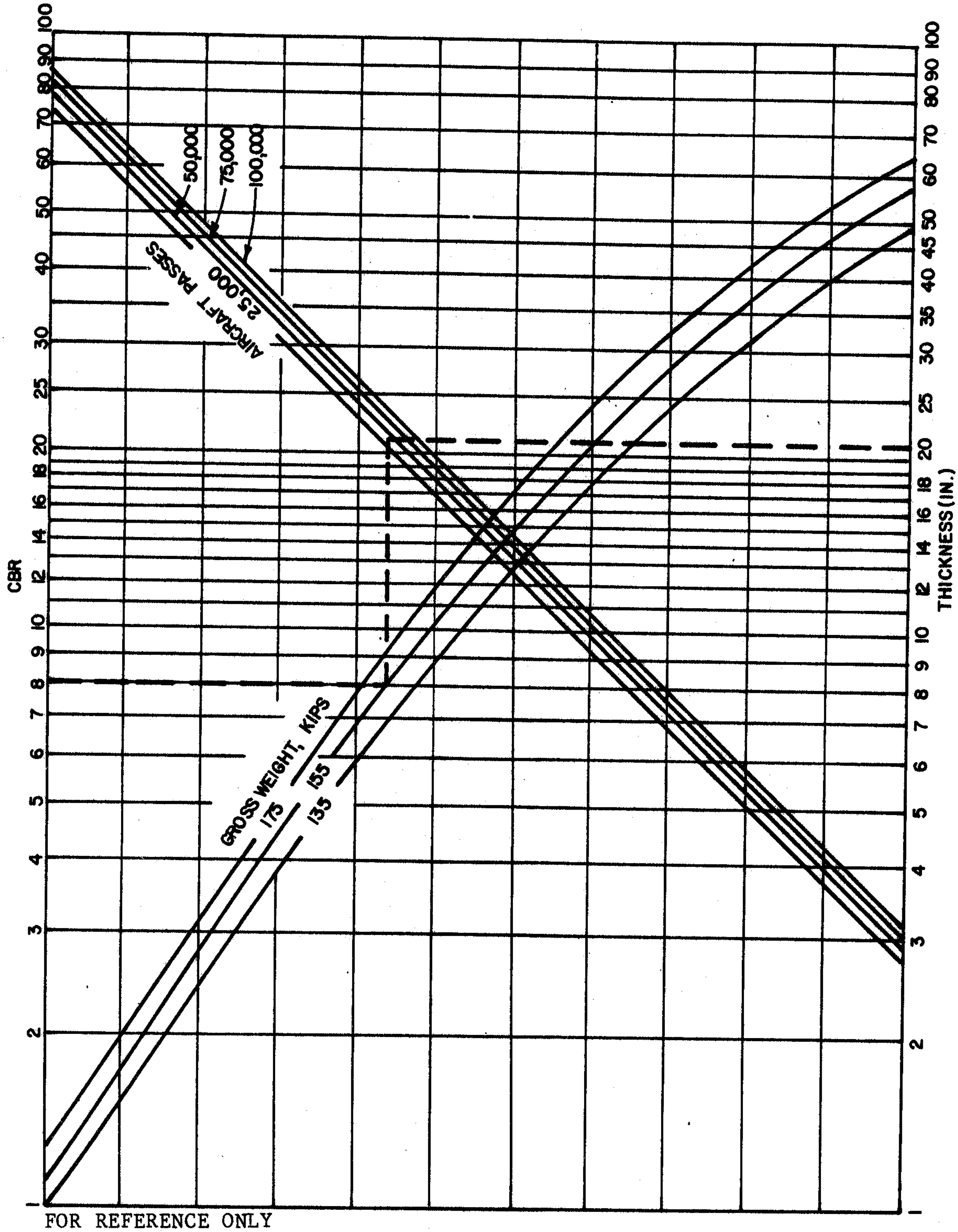

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FIGURE 7-8. FLEXIBLE PAVEMENT DESIGN CURVES, AIR FORCE SHORTFIELD PAVEMENT, TYPE A TRAFFIC AREAS AND OVERRUNS determined. These thicknesses together with the minimum thicknesses for surface and base courses provide the basis for pavement section design. Use table 5-2 for minimum thickness of base and surface course. See table 7-2 for an outline of the flexible pavement thickness design procedure. In addition, consider the following:

a. CBR values less than 3. Normally sites which include large areas of the natural subgrade with CBR values of less than 3 are not considered adequate for airfield construction. However, CBR values of less than 3 are acceptable for occasional isolated weak areas.

b. Frost areas. Pavement sections in frost areas must be designed and constructed with non-frost-susceptible materials of such depth to prevent destructive frost penetration into underlying susceptible materials. Design for frost areas should be in accordance with EM 1110-3-138.

c. Expansive subgrade. Determine if moisture condition of expansive subgrade is controlled and if adequate overburden is provided. (See table 3-5).

d. Limited subgrade compaction. Where subgrade compaction must be limited for special conditions (see tables 3-3 and 3-5), provide pavement thickness in conformance with reduced density and CBR of the prepared subgrade.

e. Rainfall and water table. In regions where the annual precipitation is less than 15 inches and the water table (including perched water table) will be at least 15 feet below the finished pavement surface, the danger of high moisture content in the subgrade is reduced. Where in-place tests on similar construction in these regions indicate that the water content of the subgrade will not increase above the optimum, the total pavement thickness, as determined by CBR tests on soaked samples, may be reduced by as much as 20 percent.

f. Pavement section comparison. Compare design pavement sections with field behavior of similar pavement sections on comparable soil conditions; assess the traffic on similar pavement sections with the design traffic loading.

7-5. Design examples. The examples are not to be used as design criteria. They are intended solely to illustrate how the criteria in this manual would be used in an assumed situation. Any attempt to arbitrarily apply these examples to actual design problems without a complete design analysis, following the procedures outlined in this manual, may result in faulty pavement design.

Table 7-2. CBR Flexible Pavement Design Procedure

Item	Procedure
Total thickness	1. Determine design CBR of subgrade (see chapter 3)
	2. Enter top of flexible pavement design curve (figure 7-1 to figure 7-8) with design subgrade CBR and follow it downward to intersection with appropriate gross weight curve, then horizontally to appropriate aircraft passes curve, then down to required total pavement thickness above subgrade.
Thickness of surface and base course	3. Determine design CBR of subbase material (see chapter 4).
	4. Enter top of curve at design CBR of subbase, follow procedure in procedure 2 above to obtain required thickness of base and surface above subbase course.
	5. Determine the required minimum thickness of base and surface from table 5-2. Increase combined thickness of base and surface to required minimum, if necessary.
Thickness of subbase course	6. Subtract thickness of surface and base from the total thickness to obtain the required thickness of subbase.
	7. If less than 6 inches, consider increasing thickness of base course.
Subgrade Compaction	8. See table 3-3 for required compaction of subgrade.

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a. Design example 1.

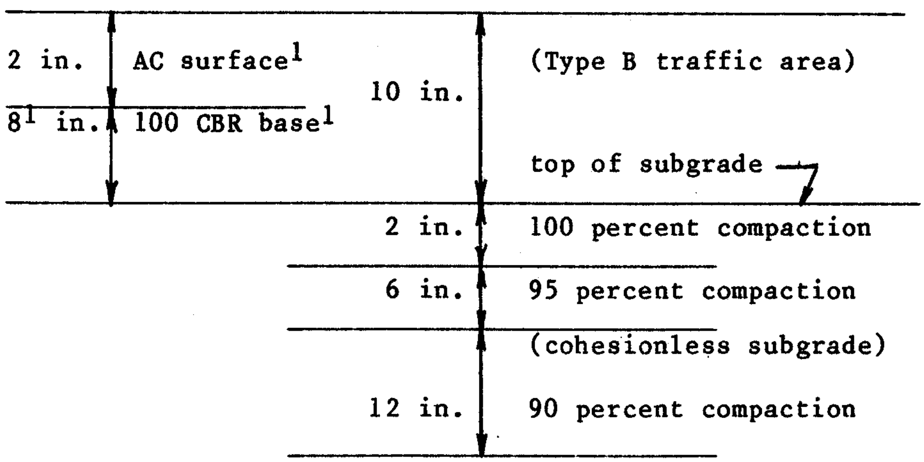
(1) Design an airfield, Type B traffic area for a single-wheel tricycle gear aircraft with a gross load of 25-kips for 1,000,000 pâsses. Subgrade is a poorly graded sand with a design CBR of 16; in-place density of the subgrade is 90 percent to a depth of 10 feet.

(2) From figure 7-1 the total pavement section required is 10 inches.

(3) From table 5-2 the minimum required surface and base thicknesses are 2 inches and 6 inches respectively, for a total of 8 inches.

(4) Use a 10-inch pavement section consisting of 2 inches of asphalt concrete surface and 8 inches of 100 CBR base on subgrade to provide the 10 inches required above the subgrade.

(5) Determine the compaction requirements from table 3-3. The design section is as follows:



[1] Base and subbase compacted to 100 percent.

Since the existing subgrade has an in-place density of 90 percent, the compaction of the 8 inch upper layer of the subgrade may be achieved by moistening and compacting in place.

b. Design example 2.

(1) Design a heavy load pavement to accommodate a 480-kip gross load twin twin gear assembly aircraft in a Type B traffic area for 15,000 passes. Design CBR of the lean clay subgrade is 13, the natural in-place density of the clay is 87 percent extending to 10 feet. The analysis that follows assumes that subgrade does not require special treatment and frost penetration is not a problem.

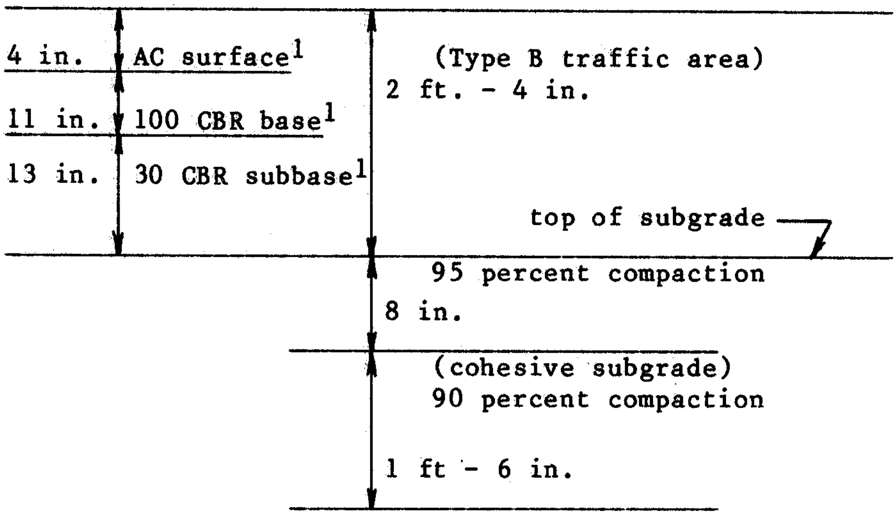
(2) Enter figure 7-6(b) at CBR = 13 down to 480-kip GROSS WEIGHT curve then right to the 15,000 AIRCRAFT PASSES curve thence down to the required thickness of pavement, 28 inches.

(3) The design CBR of the subbase material has been determined to be 30. Enter figure 7-6(b) at CBR 30 and find that the required thickness of base and surface is 15 inches for the design aircraft. From table 5-2, the required minimum thickness of the surface course is 4 inches and of the base, 9 inches. Use 4 inch asphalt concrete surface and 11 inches of 100 CBR base to provide the 15 inches required above the 30 CBR subbase.

(4) The required thickness of subbase is 13 inches (28 inches less 15 inches).

(5) From table 3-3 it is determined that for cohesive subgrade soils, 95 percent compaction is required to 3 feet below pavement surface and 90 percent compaction to a 4-1/2-foot depth.

(6) The design section is illustrated below:



[1]Base and subbase compacted to 100 percent.

7-6. Stabilized pavement sections. Stabilized layers may be incorporated in the pavement sections in order to make use of locally available materials which cannot otherwise meet the criteria for base course or subbase course. The strength and durability of the stabilized courses must be in accordance with requirements of chapters 4 and 5. (See requirements EM 1110-3-137).

a. Equivalency factors. The use of stabilized soil layers within a flexible pavement provides the opportunity to reduce the overall thickness of pavement structure required to support a given load. This is accomplished through the use of the equivalency factors presented in table 7-3. Factors are shown for replacement of base and subbase material and indicate that 1 inch of stabilized material is equivalent to the number of inches of unbound materials shown in the table. That is, 1 inch of cement-stabilized gravels or sands is equivalent to 1.15 inches of base-course material and 2.3 inches of subbase material. Any stabilized soil used to replace a base or subbase must meet the requirements described in EM 1110-3-137.

b. Design. The design of a pavement having stabilized soil layers is accomplished through the application of equivalency factors to the individual unbound soil layers of a pavement. A conventional flexible pavement is first designed, then the base and subbase are converted to an equivalent thickness of stabilized soil. This conversion is made by dividing the thickness of unbound material by the equivalency factor. For example, assume that a conventional pavement has been designed consisting of 4 inches of AC, 10 inches of base, and 15 inches of subbase for a total thickness above the subgrade of 29 inches. It is desired to replace the base and subbase with cement-stabilized GW material. The equivalency factor for the base-course layer is 1.15; therefore, the thickness of stabilized GW to replace 10 inches of base course is 10/1.15 or 8.7 inches. The equivalency factor for the subbase layer is 2.3, and the thickness of stabilized GW to replace the 15-inch subbase is 15/2.3 or 6.5 inches. The thickness of stabilized GW needed to replace the base and subbase would be 15.2 inches.

c. Use of equivalency factors. To design a pavement with an all-bituminous concrete section, the total thickness of a conventional pavement section and the thickness of the surface courses are first determined as outlined in table 7-2. Let us assume that the total thickness for a conventional pavement section is 28 inches and the required thickness for the surface courses is 4 inches. Minimum thickness requirement for the base course is 6 inches. The indicated thickness for an unbound subbase is 28 inches minus 4 inches of asphaltic concrete surface courses and 6 inches of all-bituminous concrete base or 18 inches. The equivalency factor for the subbase course layer is 2.3. The required thickness for the all-bituminous concrete bottom layer is 18 inches/2.3 or 7.8 inches (use 8 inches). The total thickness of the all-bituminous concrete section is 18 inches.

7-7. Special areas. Areas such as overrun areas, airfield and heliport shoulders, blast areas, and reduced load areas require special treatment as described below.

a. Overrun areas. Pave overrun areas for the full width of the runway exclusive of shoulders, and for a length of 200 feet on each end of Class I, II, and III runways. Surface the overrun areas with double bituminous surface treatment except for that portion (150 feet long x

Table 7-3. Equivalency Factors

Material	Equivalency Factors Base	Subbase
Unbound Crushed Stone	1.00	2.00
Unbound Aggregate	—[1]	1.00
Asphalt-Stabilized		
All-Bituminous Concrete	1.15	2.30
GW, GP, GM, GC	1.00	2.00
SW, SP, SM, SC	—[1]	1.50
Cement-Stabilized		
GW, GP, SW, SP	1.15[2]	2.30
GC, GM	1.00[2]	2.00
ML, MH, CL, CH	—[1]	1.70
SC, SM	—[1]	1.50
Lime-Stabilized		
ML, MH, CL, CH	—[1]	1.00
SC, SM, GC, GM	—[1]	1.10
Lime, Cement, Fly Ash Stabilized		
ML, MH, CL, CH	—[1]	1.30
SC, SM, GC, GM	—[1]	1.40

[1]Not used as base course.

[2]Cement is limited to 4 percent by weight or less.

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runway width) abutting the runway pavement end which will have wearing surface of 2 inches of dense graded asphaltic concrete for blast protection. Minimum base course CBR values are as follows:

Design Loading	Minimum Base Course CBR
Class III	80[1]
Class II	80[1]
Class I	50[2]

[1]Any 80 CBR type base course listed in chapter 5.

[2]Must meet all requirements for 50 CBR subbase materials listed in chapter 4.

b. Paved shoulders. Shoulder areas will be paved to support the aircraft outrigger gear and for protection against jet blast. The wearing surface will be 2 inches of dense graded asphaltic concrete; design the pavement thickness in accordance with figure 7-7.

c. Shoulders. Design shoulders adjacent to hardstand and apron areas to sustain traffic of support vehicles. Design the pavement thickness of shoulder areas in accordance with figure 7-7. Use a double bituminous surface treatment on a minimum 6-inch base consisting of 40 CBR material or better.

d. Overrun areas and other shoulder areas. Compact surface of overrun areas and shoulder areas, except shoulders adjacent to aprons and hardstands, to 90 percent maximum density for a depth of 6 inches. Stabilize the shoulders for dust and erosion control against blast of motor blades. Provide vegetative cover, anchored mulch, coarse graded aggregate, liquid palliatives, or a double bituminous surface treatment. When a double bituminous surface treatment is specified, provide a 4-inch base of 40 CBR material or better.